

METHOD AND DEVICE FOR DRIVER INFORMATION AND FOR A REACTION
WHEN LEAVING THE TRAFFIC LANE

Background Information

The present invention relates to a method and a device for
driver information and a reaction upon departure from the
lane, or, more accurately, in response to the threatening
leaving of the lane.

Warning systems, which warn the driver when he leaves the
lane, or rather, threatens to leave the lane, are known in the
related art. EP 1 074 430 A1, for example, shows a procedure
in which, based on image sensor systems, the lane in which the
vehicle is moving is ascertained, and the driver is warned
when the vehicle leaves the lane or threatens to do so.
However, information on the exact boundary conditions, under
which such a warning is given, is not stated.

Summary of the Invention

By the driver's taking into account future corrections of the
track (path) of the vehicle, in ascertaining whether, because
of a future departure from the lane, he should be warned or
not, it is possible effectively to avoid false warnings and,
nevertheless, to maintain the desired reliability of the
warning in response to the occurrence of the corresponding
traffic situation.

This makes it possible to recognize a future departure from
the lane in a particularly exact and reliable manner. This
fact and the suppression of false warnings, increases the
operating friendliness, and the acceptance of a driver
assistance system in which the driver is warned when the

vehicle leaves the lane or upon future departure from the lane, or rather, reactions are introduced which lead the vehicle back to its normal lane (such as by a steering intervention).

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In a particularly advantageous way, in response to the estimation of the future path of the vehicle, future corrections of the path by the driver are taken into consideration in an execution that includes his reaction time.

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This leads to a further improvement of accuracy and reliability of the system.

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An especially simple implementation is that an average value of the correction measures of the driver, such as a steering angle value or a transverse acceleration value is predefined, and is taken into consideration in determining the path. It is also of advantage that the state of attention of the driver is taken into consideration in forming the magnitude of such a predefined value.

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It is especially advantageous that, in the calculation of the future path of the vehicle, which is drawn upon to warn the driver when he leaves the lane, the state of attention of the driver is taken into account in such a way that the behavior of the driver in the past is ascertained, and, in response to behavior which leads one to conclude that the driver is inattentive, the possible future path of the vehicle is calculated using a smaller change in the curvature than for a driver that is presumed to be attentive. It is particularly advantageous to draw upon the steering motions or the yaw rate changes in the past for estimating the degree of attentiveness of the driver. Small steering motions designate an inattentive driver, and more forceful motions an attentive one.

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Further advantages result from the following description of exemplary embodiments, and from the dependent claims.

Brief Description of the Drawings

The present invention is explained in greater detail below, with the aid of the specific embodiments represented in the drawings.

Figure 1 shows, in this context, a block diagram of a device for warning a driver and for a reaction when the vehicle threatens to leave the lane.

Figure 2 shows a sketch of a flow chart in which a first procedure for determining the driver warning is shown.

Figure 3 makes this clearer in the light of its sketches.

Figure 4 shows a flow chart for a second exemplary embodiment, whose procedure is made clearer in the light of the representation in Figure 5.

Figures 6 & 7 show an exemplary embodiment in which the calculation of the possible future path of the vehicle is a function of the degree of attentiveness of the driver, Figure 6 showing the situation for an attentive driver, and Figure 7 for an inattentive driver.

Description of the Exemplary Embodiments

Figure 1 shows a device used for warning a driver and for a reaction in response to future leaving of the lane of the vehicle. What is shown is a control or evaluation unit 10, which has an input circuit 12, a microcomputer 14 and an output circuit 16. These elements are interconnected via a bus system for mutual data exchange. Input lines from various measuring devices, via which measuring signals and measuring

data are transmitted, are supplied to input circuit 12. A first input line 20 connects input circuit 12 to an image sensor system 22, which picks up the scene in front of the vehicle. Corresponding image data are transmitted via input line 20. Furthermore, input lines 24 to 28 are provided which connect input circuit 12 to measuring devices 30 to 34. These measuring devices are, for example, measuring devices for measuring the vehicle speed, for recording the steering angle and for recording additional operating variables of the vehicle, which have meaning in connection with the procedure described below. At least one warning device 38 is activated via output circuit 16 and output line 36, for instance, a warning lamp and/or a loudspeaker for an acoustical warning or a voice response and/or a display for displaying an image, with the aid of which the driver is informed and/or warned before the departure, to be feared, from the lane, according to the procedure shown below. In addition, or alternatively, it is provided in some exemplary embodiments that one should activate a controlling system 42 via output circuit 16 and an output line 40, which automatically leads back into the lane, for instance by an intervention in the steering of the vehicle, and thus prevents leaving the lane.

According to the procedure described below, a warning or an intervention in the vehicle movement takes place when it is estimated that the driver is no longer able to hold the vehicle in the lane using normal corrections. To do this, a check is made whether, while considering normal corrections of the driver, i.e. a certain steering angle which the driver normally uses to correct his track, the vehicle crosses the edge markings or not. The future track of the vehicle is then specifically calculated while taking into consideration these corrections by the driver that are to be expected, is compared to the detected edge markings, and a warning is emitted if the future track of the vehicle crosses the edge markings. In the determination of the value represented by the correction of

the track by the driver that is to be expected, in one supplementary exemplary embodiment, the state of attentiveness of the driver is taken into consideration. In this context, the value is the greater (this corresponds to a more forceful correction), the more attentive the driver is, and the less, the more inattentive the driver is. In this context, the attentiveness of the driver is derived, depending on the exemplary embodiment, from steering wheel movements, head posture, accelerator motion, etc.

In an additional embodiment, the reaction time of the driver is also estimated in connection with the detection of whether the vehicle will leave the lane in the future. It is assumed that, at the beginning of a warning, the driver will have a certain reaction. It has proven suitable to subdivide this reaction into several phases. In a first phase (of a duration such as 0.5 sec) no change in the steering angle takes place (reaction time of the driver to the warning); in a second phase, which borders on the first phase (of a duration such as 0.1 sec), the driver undertakes a correction away from the edge marking. He may, for example, turn the steering wheel by a certain angle (e.g. 10°) in the direction that brings the vehicle back into the lane. Alternatively to this, a rotation of the wheel is carried out so that a curve is driven that has a transverse acceleration of 2 m/sec^2 . In a third phase, which borders on the second phase, driving continues at an unchanged steering angle, until the vehicle moves in the direction of the center of the lane. Under consideration this behavior pattern, the future track for each point in time, which the vehicle will travel in case of a warning, is calculated. From this variable, the suitable point in time of the warning may then be derived, which has to take place exactly when the track, calculated in consideration of the driver's reaction, crosses the corresponding lane marking by a desired measure (which can also be negative). The range of distance in which the comparison with the edge marking takes place is limited,

in this context (for instance, to 1 sec). These measures ensure that, in each lane-leaving situation, after a warning, the driver gets away from his own lane at most only by a certain measure.

Alternatively, or in supplement of the warning, an intervention in the vehicle movement takes place, e.g. in the steering, by which the vehicle gets back to the track again in a lane-leaving situation as described above.

The above-described procedures are implemented using programs which are programmed on microcomputer 14. The latter generates the output signals for the warning or vehicle intervention, with the aid of the programs and according to the input signals supplied. In the light of flow diagrams, two preferred specific embodiments of the procedure represented above are shown below.

A first exemplary embodiment is described in the light of the flow chart of Figure 2. In this context, the program represented is run through at certain points in time.

In first step 100, the sequence of the lane marking (such as left and/or right lane edge) is read in. The sequence of the lane marking is given, in this context, in one preferred exemplary embodiment as a polynomial, such as a third order power function. This function is derived from the image data ascertained by the image sensor system. In this context, the microcomputer, using object recognition measures, recognizes the markings, and calculates the parameters of the power function from the recognized markings. In subsequent step 102 the future track of the vehicle is then calculated. The representation of this track also takes place using the function type that is used for the sequence of the lane markings. Accordingly, for example, from the current vehicle speed, the current steering angle or the transverse

acceleration, etc, the parameters of the function are calculated which calculate the pattern of at least one track (track of the left and/or right vehicle edge) of the vehicle. An additional variable, that is evaluated for the calculation of the parameters, is the predefined correction value that is preferably a function of the attentiveness state, which is worked in, for example, by the correction of the steering angle. In subsequent step 104 the two functions are then checked as to whether they intersect or whether the future vehicle track lies across the pattern of the edge markings beyond a certain measure, or whether the future vehicle track is approaching the edge markings up to a certain measure. The distance range (distance from the vehicle), to which this comparison is limited, is predefined, in this context, (e.g. 1 sec), or is predefined by the maximum measuring distance of the image sensor system. If no crossing (point of intersection) is ascertained, one must assume that the vehicle remains in the lane, and the program is ended. If, however, a crossing of the two track curves are ascertained, then, according to step 106 a warning to the driver takes place, using acoustical and/or optical means, and in one exemplary embodiment an automatic correction of the track of the vehicle, for example, by an intervention in the steering of the vehicle. The program is then ended and run through again at the next point in time.

Figure 3 shows two traffic situations, according to Figure 3a, no driver warning taking place, and according to Figure 3b, a driver warning taking place. Future lane 202 calculated for vehicle 200, which is determined, as shown above, taking into account possible corrections by the driver (e.g. fixed steering angle value), in Figure 3a shows no crossing with the edge marking shown as the dashed line, whereas in Figure 3b such a crossing is present. According to that, in Figure 3b the driver is warned at the time shown or a vehicle intervention is undertaken, since the driver will probably not

hold the vehicle in the lane only by normal corrections, while in Figure 3a the warning does not take place because the driver will be able to do so.

5 It is particularly advantageous if the extent of the assumed correcting motion of the driver is a function of his state of attentiveness. In the case of a watchful driver, the correcting movement to be expected will lie, for example, at a steering angle of 10° and a transverse acceleration of
10 2 m/sec^2 , whereas this value is clearly lower in the case of an inattentive driver. The state of attentiveness of the driver is derived, for example, from steering movements, accelerator movements, body posture, etc, and then, as a function of the degree of attentiveness, the correcting values are determined,
15 and these are incorporated in the calculation of the future track of the vehicle.

A second exemplary embodiment, which further improves the accuracy and reliability of the recognition of the existing
20 situation, is shown in the flow diagram in Figure 4. This program, too, is run through at predefined time intervals. Analogously to the procedure depicted before, here too, in step 300, a function is read in that indicates the pattern of the lane marking (right and/or left side), which was derived
25 from the image data of the image sensor system. In subsequent step 302, for first phase 4 (first time range, first distance range) one or more future tracks of the vehicle (e.g. track of the left vehicle edge and/or track of the right vehicle edge) are determined, for example, in the light of the vehicle speed
30 and the steering angle and/or transverse acceleration, etc. In this phase, the assumption is made that there is no reaction by the driver, and consequently that no change in the steering angle or the transverse acceleration takes place. It has become apparent that a time range of 0.5 sec is suitable as
35 the duration of this first phase. In this context, the track is also represented using a functional equation. In one

preferred implementation, in step 302, based on the
ascertained function, predefined points of the track of the
vehicle, which, for example lie at predetermined distances,
are determined, to which the vehicle will move towards the end
5 of the first phase. Corresponding track points (at
corresponding distances) have been ascertained with respect to
the edge marking region. Then the second phase begins, for
whose duration a time of 0.1 sec has been proven to be
suitable. In this phase the driver reacts by turning the
10 steering wheel away from the side marking. In this context, it
is assumed that, at the actual time, a warning would have
occurred. It is assumed that the steering wheel is turned by a
certain value, or rather, that the vehicle travels a curve
having a certain transverse acceleration. A 10° steering angle
15 and 2 m/sec^2 have shown themselves as suitable values.
Consequently, in step 304, starting from the end point of the
track of the first phase, a track of the vehicle for the
second phase is determined, an appropriate correction of the
steering angle and/or of the transverse acceleration being
20 taken into consideration in the determination of the
parameters of the function. After the end of the second phase,
it is assumed that the vehicle will continue on at an
unchanged steering angle, so that in one exemplary embodiment
(not shown in Figure 4) an additional track calculation takes
25 place. In the second phase also and possibly the third phase
too, in one preferred implementation, individual track points
are calculated at certain distances. After determination of
the future track curve of the vehicle, checking is done in
step 306 as to whether the function of the pattern of the lane
30 marking has crossings with the track curves of the first or
second phase. This is done by evaluating the function
equations or by comparison of the coordinates of corresponding
track points. If this is not the case, then it is assumed that
a situation is not present in which the vehicle's leaving the
35 lane is a threat. However, if a crossing is detected, then
according to step 308 an optical and/or acoustical warning is

given to the driver and/or a vehicle intervention for the automatic correction of the steering is ascertained and carried out. The program is then ended and run through again at the next point in time.

5 In an advantageous manner, both in this procedure and the one depicted in the light of the first exemplary embodiment, the loudness of the warning, in the case of an acoustical warning, may be made variable and a function of the state of attentiveness of the driver.

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The effectiveness of the procedure shown in Figure 4 is made clear in the light of the illustration in Figure 5. An x/y coordinate system is drawn in, whose centroid lies, for example in the middle of the vehicle. In this context, vehicle 15 400 travels in a traffic lane which is characterized by edge markings 402 and 404. Two tracks of the vehicle are also drawn in, one left and one right (406, 408) which describe the course of the left and the right vehicles edges. As was pointed out above, the course of the left and the right side 20 markings (402, 404) relative to the vehicle are ascertained by a camera system. The course of the track markings is then shown with the aid of a mathematical equation, preferably a third order power function. In this way, the side markings are able to be calculated, for instance by the five points A, B, 25 C, D, E for the left side markings, and by the points F, G, H, J, K for the right side markings. These points are selected so that, on the assumption of constant travel speed of the vehicle, they lie at certain time intervals ahead of the vehicle (e.g. A, F at 0 sec, B, G at 0.25 sec, C, H at 0.5 30 sec, D, J at 0.75 sec and E, K at 1 sec). To determine the tracks of the vehicle, paths 406, 408 are ascertained for the left and the right track of the vehicle. In this context, the travel speed and the current steering angle and/or the transverse acceleration of the vehicle make a difference. It 35 is assumed that the vehicle travels at least in the next 0.5 sec using an unchanged steering angle (phase 1). This

corresponds to the area between points A and C, and F and H, respectively. The track of the vehicle is also represented by a mathematical equation corresponding to the representation of the pattern of the lane markings. In this way, within the extent of the first phase, points L, M, N may be determined for the left track and Q, R, S for the right track. In this context, the equations are set up in such a way that the left edge of the vehicle travels through the curve from L to N, and the right edge from Q to S. It is further assumed that the driver, if he were warned at the point in time shown, will, after ca 0.5 sec turn his steering wheel by a certain magnitude (e.g. ca 10°) in the right direction, in order to avoid leaving the lane. In this way, in phase 2 (area C to E and H to K, respectively, broken line area in phase 2) a new curve having a changed steering angle and/or a changed transverse acceleration is determined, which are determined by the points N, O and P and S, T and U, respectively. In this context, the track points of the vehicle tracks are calculated for the same distances as the track points of the lane markings, so that corresponding value pairs are formed. Thereafter, the patterns of the curves are compared (right track curve to right side edge curve, left track curve to left side marking curve) as to whether there are crossings or not. This takes place in the implementation shown by comparison of the y coordinate of corresponding track points. Thus, a warning on the left side takes place if either L lies above A, or M above B, or N above C, or O above D or P above E. Similarly, a warning on the right side takes place if either Q lies below F, or R below G, or S below H, or t below J or U below K.

As an alternative to this, the warning takes place only if one of the points L to P lies above one of points A to E by a certain measure, as well as if one of points Q to U lies below one of points F to K by a certain measure. In this context, the value of the measure that was mentioned may also be

negative. So that even an approach to the lane marking generates a warning. In this way, tolerances are taken into consideration.

5 In this context, depending on the embodiment, the warning may take place on both vehicle sides or only on one vehicle side.

10 In the exemplary embodiment just shown, the future track of the vehicle is calculated on the basis of a supposedly fixed steering of the driver. In practice it turns out that, in the case of some drivers, relatively many false warnings may occur if such a driver swings back and forth between the lane markings.

15 Therefore, in an additional advantageous exemplary embodiment the warning threshold for triggering the lane-leaving warning is dynamically changed by taking into consideration the degree of attentiveness of the driver when the calculation is made of the future track of the vehicle. The calculation of the future
20 track of the vehicle, and therewith the warning threshold for triggering the warning becomes, in this context, a function of the behavior (performance characteristics) of the driver in the recent past. Depending on how much the vehicle travels curved tracks because of the steering movements of the driver,
25 the calculation of the future track of the vehicle, and thereby also the warning threshold itself are modified. In the case of attentive drivers, this avoids many false warnings, but in the case of inattentive drivers, the warnings are triggered at the right time.

30 In general, in the above exemplary embodiment, a warning is triggered if a left warning boundary touches the left lane marking, or the right warning boundary touches the right lane marking. In this context, the warning boundary represents the
35 future track of the vehicle, taking into consideration a possible estimated steering correction by the driver, if the

latter drives closely towards the respective lane marking. The future track of the vehicle, and therewith the warning boundary are therefore curved. It has turned out that an inattentive driver, who is supposed to be warned by the system, as a rule makes very slight steering movements before leaving the lane. Therefore the vehicle travels a path having a relatively constant curvature. Now, it is essential that, in the present exemplary embodiment, the warning boundaries be brought in with respect to each other if the curvature of the track that has been traveled by the vehicle has changed considerably (i.e. if comparatively strong steering movements have been executed by the driver). This means that a greater curvature of the future track of the vehicle away from the lane marking is assumed. In response to a relatively constant curvature of the traveled track (and thus at very slight steering movements of the driver) the warning boundaries are broadened out, i.e. the possible future track of the vehicle is calculated using a lower change in the curvature.

In Figures 6 and 7 the vehicle is shown as 400. Furthermore, the left and right lane marking are shown as 402. 404 shows the future course of the vehicle without consideration of steering wheel changes, while the left and right warning boundaries are shown as 406 and 408, respectively. In this context, the left and right warning boundaries represent the future track of the vehicle while taking into consideration the correcting interventions of the driver. In this context, Figure 6 shows the situation in response to an attentive driver, while Figure 7 shows the situation in response to an inattentive driver. Consequently, in Figure 6 the curvature of the vehicle's course changed greatly in the past. It is for that reason that the warning boundaries run close together. In other words, the courses of the warning boundaries show a great deviation from the future course of the vehicle without steering correction. If the vehicle approaches the right or the left lane marking, a warning occurs only at a late time.

In Figure 7 the situation is different. In the near past, the curvature of the course of the vehicle has hardly changed, and therefore the warning boundaries lie wide apart at a certain distance ahead of the vehicle. Thus, the courses of the warning boundaries here show a lesser deviation from the future course of the vehicle without steering correction. If the vehicle approaches closer to the lane marking, a warning is triggered in good time.

In the preferred exemplary embodiment, this behavior is implemented in that, with the aid of steering movements, recorded, for example, from the signal of a steering angle sensor or a yaw rate sensor, a factor is determined using which the predefined correcting value is weighted. Consequently, when the calculation is made of the future track of the vehicle, and with that the course of the warning boundaries, a large correcting value is assumed in response to strong curvatures and steering movements, which leads to a greater change of the curvature of the future track, and with that, a drawing together of the warning boundaries, while in response to small steering movements in the past, a lower curvature factor is assumed, and consequently the warning boundaries lie far apart. In this context, the implementation takes place preferably, as described in the case of the exemplary embodiments described above, within the scope of a computer program.

The drawing together of the warning boundaries that was shown is not only undertaken as a function of the past of the vehicle's course, but, in one exemplary embodiment, alternatively or additionally even at time periods in which, for example, the measurement of the lane markings is uncertain. Therefore, in such situations a large factor is specified, which leads to a great curvature of the warning boundaries, and consequently to a drawing closer together of the warning boundaries. This avoids unnecessary signals as a

response to uncertain recording of lane markings.

In other exemplary embodiments, besides recognition of the attentiveness of the driver in the light of the curvature of the course of the vehicle in the past, or in the light of
5 steering movements, a different recognition of attentiveness, such as one derived from accelerator movements, head posture, etc, is used.